

What is claimed is:

1. A medical device programmer comprising:
  - 5 an antenna to receive a signal transmitted from an implantable medical device, the signal including a carrier signal modulated with transmit pulses by amplitude shift keying, the transmit pulses generated by the implantable medical device;analog receiver circuitry coupled to the antenna;
  - 10 at least one filter coupled to the analog receiver circuitry, the at least one filter having frequency characteristics dynamically adjustable based on at least one peak frequency in a noise spectrum of the received signal;a noise spectrum detector, coupled to the at least one filter, to detect the at least one peak frequency in the noise spectrum; and
  - 15 a pulse detector, coupled to the at least one filter, to detect the transmit pulses.
2. The programmer of claim 1, wherein the signal has a bandwidth of approximately 10 to 150 kilohertz.
3. The programmer of claim 1, further comprising an analog-to-digital converter,20 coupled between the analog receiver circuitry and the at least one filter, to digitize the received signal, and wherein the at least one filter comprises at least one digital filter having dynamically adjustable filter coefficients.
4. The programmer of claim 3, further comprising a filter synthesizer, coupled25 between the noise spectrum detector and the at least one filter, to synthesize the at least one filter based on the at least one peak frequency in the noise spectrum.
5. The programmer of claim 4, wherein the at least one digital filter comprises at least one digital notch filter to remove narrowband noise from the received signal.

6. The programmer of claim 5, wherein the at least one digital notch filter has a notch frequency corresponding to the at least one peak frequency in the noise spectrum.
- 5 7. The programmer of claim 6, wherein the at least one digital notch filter comprises an infinite impulse response (IIR) notch filter.
8. The programmer of claim 6, further comprising a digital matched filter, coupled between the at least one digital notch filter and the pulse detector, to remove broadband noise from the received signal.
- 10 9. The programmer of claim 8, wherein the digital matched filter comprises a finite impulse response (FIR) filter having coefficients derived based on a transmit pulse expected to be generated by the implantable medical device.
- 15 10. The programmer of claim 9, wherein the digital matched filter has coefficients derived based on a captured noise-free signal transmitted from the implantable medical device.
- 20 11. The programmer of claim 9, wherein the digital matched filter is adapted to perform a convolution between the received signal and a signal corresponding to a time-reversed version of the transmit pulse expected to be generated by the implantable medical device.
- 25 12. The programmer of claim 8, wherein the pulse detector detects the transmit pulses by comparing an output of the matched filter with a threshold value.

13. The programmer of claim 12, further comprising:
  - a noise peak detector, coupled to the digital matched filter, to detect peak noise values in the digitized received signal;
  - a signal peak detector, coupled to the digital matched filter, to detect peak signal values in the digitized received signal; and
  - 5 threshold adjustment circuitry for adjusting the threshold value based on the peak noise values and the peak signal values.
14. A medical device programmer comprising:
  - 10 means for receiving a signal transmitted from an implantable medical device, the signal including transmit pulses generated by the implantable medical device; and
  - means for removing narrowband noise from the received signal, including:
    - means for detecting a noise spectrum of the received signal;
    - means for detecting frequency peaks in the noise spectrum; and
    - 15 means for synthesizing one or more filters based on the detected frequency peaks in the noise spectrum.
15. The programmer of claim 14, further comprising means for removing broadband noise from the received signal by correlating the received signal with a transmit pulse expected to be generated by the implantable medical device.
  - 20
16. The programmer of claim 15, further comprising means for detecting the transmit pulses by comparing an output of the means for removing the broadband noise from the received signal with a threshold value.
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17. The programmer of claim 16, further comprising means for adjusting the threshold value based on the received signal.

18. The programmer of claim 17, wherein the means for adjusting the threshold value comprises;

means for detecting peak noise values from the received signal;

means for detecting peak signal values from the received signal; and

5 means for dynamically adjusting the threshold value based on the peak noise values and the peak signal values.

19. A method comprising:

receiving a signal transmitted from an implantable medical device, the signal 10 including a carrier signal modulated with transmit pulses by amplitude shift keying, the transmit pulses generated by the implantable medical device;

detecting a noise spectrum of the received signal;

detecting one or more peak frequencies in the noise spectrum;

15 adjusting frequency characteristics of one or more filters based on the detected one or more peak frequencies in the noise spectrum;

filtering the received signal using the one or more filters; and

detecting the transmit pulses from the filtered received signal.

20. The method of claim 19, wherein adjusting the frequency characteristics of the 20 one or more filters comprises dynamically synthesizing one or more digital notch filters to remove narrowband noise.

21. The method of claim 20, wherein dynamically synthesizing the one or more digital notch filters comprises dynamically adjusting notch frequencies according to the 25 detected one or more peak frequencies in the noise spectrum.

22. The method of claim 21, wherein dynamically synthesizing the one or more digital notch filters comprises dynamically adjusting filter coefficients of one or more infinite impulse response (IIR) filters.

23. The method of claim 21, wherein detecting the noise spectrum of the received signal comprises:

computing a power spectrum,  $P_i$ , of the received signal; and  
5       computing the noise spectrum,  $P_n = P_i - R * P_e$ , where  $P_e$  is a template spectrum precomputed from a representative received signal generated under noise-free conditions, and  $R$  is an average ratio of  $P_i$  to  $P_e$ .

24. The method of claim 23, furthering comprising computing spectral threshold values for detecting the peak frequencies in the noise spectrum based on a mean and a 10 standard deviation of  $P_n$ .

25. The method of claim 24, wherein computing the spectral threshold values comprises setting the spectral threshold values at three standard deviations above the 15 mean of  $P_n$ .

26. The method of claim 20, further comprising filtering the received signal with a matched filter to remove broadband noise.

20   27. The method of claim 26, wherein filtering the received signal with the matched filter comprises performing a convolution between the received signal and a digital signal corresponding to a time-reversed version of a transmit pulse expected to be generated by the implantable medical device.

25   28. The method of claim 26, wherein filtering the received signal with the matched filter comprises deriving filter coefficients based on a transmit pulse expected to be generated by the implantable medical device.

29. The method of claim 28, wherein deriving the filter coefficients comprises deriving filter coefficients for a finite impulse response (FIR) filter.
30. The method of claim 28, wherein deriving the filter coefficients comprising 5 capturing a noise-free signal transmitted from the implantable medical device.
31. The method of claim 26, wherein detecting the transmit pulses comprises comparing an output of the matched filter with a threshold value.
- 10 32. The method of claim 31, further comprising:  
detecting peak noise values in the received signal;  
detecting peak signal values in the received signal; and  
adjusting the threshold value based on the peak noise values and the peak signal values.